SYNCHRONISING KNOWLEDGE OF COSTS WITH ESTIMATES.

Presidential Address by the President of the Institution, Sir Walter Kent, C.B.E., delivered at the Glasgow Section.

A PRESIDENTIAL Address to an assembly of able men is no mean responsibility. The range of subjects is so wide, and the method of approach so varied that to make a choice is most perplexing. An address may display erudition; excite imagination by revealing a new vista of possibilities; or, more humbly, suggest a means of discharging better some of the duties of those for whom it is written. Your President is not competent to do either the first or the second, and will therefore try his best at the third. It was wisely said by our General Secretary that "the science of production is so closely linked with the art of management and the ethics of 'personnel' relations that the task of making production an exact science is well nigh impossible." It is to the art of management as practised in the costing department that this address would apply itself. But before embarking upon this mission may a brief word be said pursuant to the tenor of the writer's inaugural address last year about the world position.

The problem of production and consumption is still with us, and, because of its long continuance, in even more acute form. These economic twins are perpetually squabbling and competing, but each is ever sensitive to the other's ill. Very little want of balance disturbs the harmony of their relations. But, think as one may; read the books and papers of economists and masters of thought—such as Philip Gibbs' "Way of Escape"—one is merely confronted with the welter of world-wide confusion, and the counteracting surges of the waves of conflicting theories.

Amidst these troubled waters Great Britain is fortunate to stand out as a rock lit by the rays of returning dawn, though still threatened and distressed by the surrounding ills of other countries.

But industry and commerce, in these days of rapid transference of thought and will, and of transport of people and goods, are world-wide in their actions and reactions, and while England, with her balanced budget and returning tide of trade, enjoys a more favoured position than other countries, it is inevitable that her progress is retarded by the adverse conditions of the other nations of the world.

Glasgow, October 25th, 1934 (Vol. XIV, No. 1, January, 1935).

It is most earnestly to be hoped that a solution of these world-wide troubles may be within measurable distance, else one fears a veritable cataclysm of civilisation.

Brave and gargantuan experiments are being tried—such as those of Mr. Roosevelt in the U.S.A. Restriction schemes are being enforced : but through all, the appalling fact confronts us that food and commodities are being deliberately burnt or destroyed in some parts of the world which, in others, would save the population from famine and starvation.

What is or are the root cause or causes ? No one can tell. Some aver that the very so-called remedial measures, such as the inflation of currency or the closing down of exchanges, are great aggravations, if not mainly responsible for our troubles. Others argue that the more immediate sequelæ of the Great War in the shape of a new map of Europe, war debt repayments, gold hoarding, and the startling economic growth and industrial development of the East are the main causes of western chaos. Then again there is the school that contends that it is the perfervid activity of the Machine Age that has produced our woes. Both in the shop and in the field—in industry and agriculture—man has been displaced by the machine during the last decade with ever accelerating pace. But as to this let us not forget that so far in the world's history machinery has, in the long run, multiplied employment. True, at the moment of its introduction it has lessened it—its very object—but, by cheapening the article produced, sales have expanded and employment has increased, not only in making but also in distributing and in selling. To-day's population could not live were it not for the help of the machine. If, therefore, we may judge the present by the past, the machine is yet the servant and support of humanity, unless there be a point of saturation, and we have reached it.

Well, now, to endeavour to give effect to the intention with which I started this address, viz. : the better functioning of the costing department.

The genesis of the scheme that we employ in our business was as follows :

For many years I had felt dissatisfied with the costing system employed in our business. The cost of production was not known soon enough, and when the estimate was exceeded it was too late to remedy the trouble, and sometimes even difficult to ascertain the precise cause. Particularly was this the case where successive batches of one production were going through the works, when it was obviously harder to keep check on the cost of each in relation to the stage of manufacture it had reached.

After the war, when our works—as nearly all others in the country—had to be reorganised in order to resume our pre-war trade, the problem was attacked in greater earnest, and a system, known by us

as the Trading Accountancy Scheme, was introduced and has been successfully applied ever since.

Of course, I am well aware that there are many systems that would have afforded the synchronous information that was desired, but the machinery for these was so elaborate and so expensive, both in installation and in running, that all were rejected. One feared that the condition might be produced which has been described in that very humorous tale of the firm who found one of these so great a success that they abandoned production and were all engaged in working the system !

On the other hand, it was not to be tolerated that the old inefficient and almost useless methods of costing should be continued. In examining the possibilities a scheme was evolved by which the desired result was attained at a cost of only two additional junior girl clerks—the total number of employees being about 1,250.

This was made possible by utilising the wage analysis, which already existed as a component part of the system of payment by results.

When it is mentioned that by the use of the Trading Accountancy Scheme (or T.A.S. as we call it) we have been able to keep our costs of production within our estimates, and, at the same time to calculate our stock value from year to year, or at any quarter, with an accuracy within ½ per cent. to 2½ per cent. of the actual figure revealed by the annual stocktaking, nothing further need be said as to its success.

It will be seen, from the details given later, that the broad outline of the T.A.S. is to give a separate credit for the items of labour, material, and tools for each job, and to debit against them the expenditure actually made, *as and when it occurs.* Part of the scheme deals with that very important cost factor, viz. : overheads. These trade charges are taken as a percentage on labour based upon an estimated turnover. Some of these, of course, are fixed, and merely have a different percentage value according to the volume of trade. But others are fluctuating, and the method of dealing with these by means of a division of responsibility is referred to below.

It would have been ideal if expenditure on labour and material could have been allotted dates of incidence as well as amounts, as this would have afforded a check upon the rate of production as well as upon the cost. But even without incorporating this in detail, general working does constitute a record of progress which is examined every week, and which causes inquiries to be made when a job hangs fire.

The complete time-check would, of course, be comparatively simple in a business of few types of production and regular demand, but would be found both difficult and complicated in a business of many production, many clients, and uncertainties of demand.

THE SCHEME IN GENERAL.

The Trading Accountancy Scheme consists of checking all expenditure on labour and material against estimates, both for productive and unproductive work, and provides an immediate knowledge of the relation of all outgoings to all incomings expressed in terms of money.

While the example of a quarterly balance sheet given further on sets forth clearly the working of the scheme in its entirety, the key to success is the *concurrent* checking of the actual against the estimated cost of labour and material, and, viewed by and large, assumes the following form :

DEBIT.	CREDIT.
(1) To actual labour cost as extracted from the weekly wages sheets.	(1) By estimated labour cost.
(2) To actual material given out extracted weekly from the stores issues.	(2) By estimated material cost.

Subsidiary items that may be regarded as part of direct cost, such as patterns and tools, are taken into the above account, but need not be detailed here.

THE SCHEME IN DETAIL.

Labour.

The estimated amount of labour required to complete each order that is placed in the shops—whether this be a running order for large quantities or a single order for a single part—is entered by the estimating office on a copy of the actual order to the shops issued by the works order office, and this copy is then passed to the cost office, where a labour account is opened with and delivered to the departmental head or heads concerned with the execution of the order.

This account is credited with the estimated labour and is debited with each week's expenditure extracted from the wages analysis under each job number. A representative of the cost office visits each departmental head *weekly* to examine all the open accounts, and to report any unsatisfactory features of either under or overspending. A summary of excess expenditure is reported to the works manager weekly, who deals with the matter on the same lines as described below in connection with defective or incorrect material. A time table is drawn up showing when this weekly review of costs will take place, and copies of this time table are posted in the offices of each department.

Labour on Defective or Incorrectly Worked Material.

Where labour has been expended on material afterwards found to be defective or incorrect, an *excess labour note* is issued by the departmental head giving full particulars of the labour so spent. One copy of this note is sent to the works manager and one copy to the cost office where the departmental labour account is credited with the appropriate amount, and if the excess labour is due to the incorrect nature of any preceding operation, the department at fault is debited correspondingly. Such debits figure in the bonus scheme described below.

Material.

The material in terms of the value estimated to be required for each job is treated in the same way as labour ; that is to say : when a job is given out it receives credit for the amount of material estimated, and it is debited with all the material actually used under that job number.

Inspection of Material.

There is no occasion to refer to the ordinary works routine by the stores and inspection departments. Any faulty part or material found subsequently in the shops is treated as follows :

The head of each department is supplied with a material rejection book, and he enters therein all material that he returns to stores for replacement. This book is taken to the stores with the material that is being returned, and the book is signed by the storekeeper, to whom one copy of the rejection note is given, which will accompany the goods back to the inspection department, and after the goods have been examined and agreed as rejections they are sent by the inspection department to the packing department for return to suppliers, or, in the case of castings of our own make, to the foundry. The packing department sends a copy of the usual dispatch note to the invoice office in order that credit may be applied for.

One other copy of the rejection note is sent to the cost office where the rejection is noted and the copy forwarded to the invoice department. It is then checked against the dispatch note above referred to.

The material rejection book itself is collected from each department once a week by the cost office for the purpose of adjusting the appropriate accounts.

Replace or Duplicate Material.

When material has been returned to stores under the heading of "rejection of material," the rejection note of the departmental head

represents authority to the stores concerned to replace the rejected parts by an equal quantity of good ones, booking out the replacements in the usual way.

Bonus Scheme.

A financial interest is offered to each department upon the saving on the estimated labour of all jobs finished in each quarter, and a further similar interest where it is possible to effect a saving upon material—such as in rod metal by the use of thin parting-off tools.

These bonuses are shared in proper proportions by the heads of departments, foremen, and charge hands: the bonus for each departments stands by itself.

It may be thought that this system would tend to produce inferior work, but two causes prevent this: one, the keenness of all departments to produce work of the highest standard; the other, the rigid system of inspection, most of our products having to pass specified working or running tests before being sent away.

With regard to the material bonus, it is perhaps worth recording that before this system was introduced there was a constant difficulty in getting the estimated number of parts produced from a definite length of rod, etc., and in one case, where a very large number of parts were being turned out in the automatic shop, there was, under the old system, a deficit of 11 per cent. in the material, which, without any alteration but the above incentive towards economy, was turned into a surplus of 13 per cent. This was effected partly by greater care in preventing scrap, but very largely by the use of thinner parting-off tools.

On-costs or Trade Charges.

These, as mentioned above are, of course, divided into two groups, viz.: the fixed charges, such as rent, rates, upkeep of premises, insurance, salaries, etc., and those which are either directly, or in some measure, dependent upon the volume of work going through the shops. As already mentioned, the fixed charges are taken as a percentage upon the estimated sales.

The variable charges are subdivided into two headings: (*a*) those which are partly, and (*b*) those which are directly affected by the volume of trade.

With regard to (*a*), such as experimental and research work, light and power, there is in each case a budgetted figure which is checked by means of a curve showing the actual against the budget from week to week. Charges under (*b*) are taken as a percentage upon the direct labour—tools, inspection, and, to some extent, labouring and storekeeping. Curves are also kept for these—indeed for all on-cost items that are not absolutely rigidly fixed. The

responsibility for these items falls upon the departmental head, and its sense is of very great help towards economical working. For instance, in the item of perishable tools, before the expenditure thereon was checked as a percentage on the direct labour of each department, the amount expended was greatly in excess of the money required under the present bonus system.

Quarterly Accounts.

An account, to which reference has been made previously, is prepared quarterly, and is debited with the total expenditure on labour (including inspection) and material, and additionally with the cost of patterns and tools and with overheads and general expenses. The total sales are, of course, shown on the credit side.

There remains to be considered any variation in stock which may have occurred during the quarter and the account needs correction in this respect, the procedure being as follows:

A figure, known as the *index figure*, for each class of manufacture is obtained from the estimates. This figure represents the ratio provided in the estimates for labour, inspection, and material in relation to the selling price. The sales are dissected under classes of manufacture, and the appropriate index figure is applied to each class. This gives the estimated labour and material required to produce the sales providing each job has been completed exactly to estimate, and should this not be the case—which is determined by the departmental accounts—the figure is adjusted accordingly.

This adjusted figure is now substituted for the actual labour and material, and the account balanced.

The extent of the stock movement is ascertained by a comparison of the adjusted figure with the actual expenditure on labour and on material issued; an increase or decrease in stock is thus indicated. This, however, forms only one factor in the stock variation which has to be further adjusted by the difference between the material issued and the material purchased.

An example of a quarterly trading account, the figures of which are entirely supposititious, will perhaps supply a clearer conception of the *modus operandi*. The figures of the fourth quarter of the year, for which the yearly stock valuation is available, provide the "proof of the pudding."

Supposititious Trading Account for the Quarter Ending, March 31st, 1936, without giving consideration to the movement of stock as effected by the difference between the Material Purchased and the Material Issued.

	£		£
Direct labour, material and inspection ...	46,500	Sales	70,750
Patterns (labour and material)	400		
Tools (labour and material)	2,900		
General expenses ...	20,000		
Cash discounts ...	200		
Reserve for bad debts and depreciation ...	1,000		

Corrected labour and material calculated by application of the appropriate index figure to the individual classes of sales (£70,750)	39,250
Deduct savings on estimated labour and material in some departments	1,500
	£37,750
Add excesses on estimated labour and material in other departments	500
	£38,250

ACCOUNT AS THUS CORRECTED :

	£		£
Direct labour, material and inspection ...	38,250	Sales	70,750
Patterns (labour and material)	400		
Tools (labour and material)	2,900		
General expenses ...	20,000		
Cash discounts ...	200		
Reserve for bad debts and depreciation ...	1,000		
Balance being profit...	8,000		
	£70,750		£70,750

EFFECT ON STOCK without regard to Profit or Loss.

	£		£		£
Calculated lab. and mat. as corrected	38,250	Actual lab. and mat. ...	46,500	Inc.	8,250
Trade material invoiced	25,000	Trade material issued ...	30,000	Dec.	5,000
		Net stock increase			3,250

N.B.—The above figures are entirely supposititious.

In conclusion it is not claimed for the system above that it is unique, as it must of necessity run on broad lines very similar to those adopted in many other works.

It has, however, been grafted into the organisation of our works with singularly little trouble or expense—only two junior clerks, as already mentioned—and has served to give no small sense of security and relief from uncertainty by the accurate knowledge afforded of the trading position of the works at any moment.

If any of the members of our Institution should think sufficiently well of it to consider its adoption, it would be a great pleasure to provide any further particulars, together with copies of the printed forms (which are but few) that are used in running the scheme. If any help could thereby be given it would be of more than sufficient reward to me for any trouble that has been taken in the preparation of this address.

Vote of Thanks.

MR. W. PATE, Member of Council: Judging from the audible evidence there is no room for hesitation so far as my immediate task is concerned, which is the moving of a vote of thanks to Sir Walter Kent for his Presidential Address and for having come to Glasgow to deliver it. And it is not only because he has made it a unique occasion that I would like on behalf of the Glasgow Section to assure Sir Walter of our great appreciation of his interest and to thank him for the personal trouble involved in paying us this compliment.

We are particularly indebted to our President for the subject he has chosen. He has indicated the intensity of competition at home as well as abroad and has directed our attention to the importance of knowing quickly and exactly what is taking place in our works. That is an old trouble and a very real difficulty, but he has given us matter for very careful thought and some very useful guidance as to how we might apply the general outlines of his scheme.

Again at the commencement he referred to competition from the East, and the other night I perused some figures worth mentioning as related to the subject and indicating the increasing importance of the science of production in this country so appropriately referred to as the science of manufacture combined with the art of management. It is estimated that in about forty years the population of Great Britain will be some ten or twelve millions down. The population of Japan will be up by a corresponding margin. Another statement was to the effect that there will be by that time more men over the age of 65 than youths under 15. I am merely quoting these estimates without attempting to support them, but they go to show that if we are to maintain our relative position we must concentrate on efficiency of manufacture because we will have to keep our costs steadily going down with a smaller number of workers to call upon and with a lower standard of living competing against us. It therefore behoves us to tackle this question of live costing as essential to success in the end. Our President has focused our attention on a most engrossing problem and I have pleasure in moving a vote of thanks to Sir Walter Kent for his address.

MR. W. F. DORMER, Member of Council, in seconding the vote of thanks, congratulated the Glasgow Section on the progress they were making and on the excellent accommodation provided for their meetings. There was shortly to be a new section of the Institution in Scotland, for on the previous evening Sir Walter Kent presided over a conference in Edinburgh where the formation of a section was decided on.

MR. JAMES WRIGHT, President of the Glasgow Section, who occupied the chair, supported the vote of thanks, which was adopted with acclamation, and suitably acknowledged by Sir Walter Kent.

ELEVENTH ANNUAL DINNER OF THE INSTITUTION.

THE eleventh annual dinner of the Institution was held on Friday, November 16th, 1934, at the Connaught Rooms, London. Sir Walter Kent, C.B.E., President, was in the chair, and there was a large attendance of members and visitors.

The toast of " His Majesty the King " having been duly honoured, Dr. E. L. Burgin, M.P., Parliamentary Secretary to the Board of Trade, proposing the toast of " The Institution," said : Mr. President and Gentlemen. An inspector returning from a visit to Smithfield a day or two ago made a report to his Department. It began with " Meat in the mass is repulsive." I am glad to see you. As a Junior Minister in the House I have to clock on and off, and to-night, in order to explain my absence, I said I was to be a guest of an Institution. They said " What, again ? " But what a remarkable thing a British Institution is. For instance, the headmaster of a famous public school was in Paris recently and was asked to explain in French the exact significance of an English public school. His French, as you would expect from a headmaster, was not too brilliant, but translated, the first sentence was this : " A public school is one which is essentially private." Many of our institutions are completely baffling.

Now for a little bit about your Institution. I, as a humble student did not know how to begin to find out anything about your Institution so I looked at the Syllabus of Fixtures, and under the Glasgow Section I find that at an early date in 1935 you are to discuss " The Control and Distribution of Overhead Expenses." I think that is a good subject to discuss. But why stand under the Glasgow Section and not under Aberdeen ? Then under another section in 1935 I find the Section President's address—O how descriptive of much in this country and elsewhere !—" Some Unusual Production Methods." There is a wealth of meaning in the title and a wealth of understanding on the part of some of us as to what it may cover and what it is not likely to. Then under the London Section, as we should expect, we find that on a date in April there is " Synthetic Compounds "—clearly a reference to the National Government.

I am never prepared to take second-hand information such as your own publications—I have to go to the root of things—and I said to myself " What on earth is a production engineer ? " One definition given to me was " He is not unlike the colonial producer of beef products. A beef producer in the Argentine produces, besides the carcase, the offal which is known as 'gluts.' The

production engineer in time of plenty does his best to produce 'guts'—the only difference is that the *l* is silent in one.

I always admire an institution that has a bit of conceit—I admire yours. You are the ambit of your influence—you are millionaires, only I admit in a figurative sense. Engineering, classed as a group, turns out something rather over 450,000,000 pounds sterling of products in the course of a normal year, and Engineering (treated as meaning mechanical, electrical, motor-cycle, aircraft, shipbuilding, railway carriage and wagon—those six groups together) employs something over a million operatives. There are only 12½ million insured workers in the entire United Kingdom. Two million of those 12½ are engaged in distributive trades. Of the remaining 10½ one million are in coal mining; another million in building, and over a million in engineering. You have, therefore, by a simple process of calculation, rather a large proportion of the available insured workpeople in the producing trades directly under the influence of your own Institution, and in the opinion of the Board of Trade that is a very fine and significant fact.

You are a most healthy Institution, and in the official brief supplied to me by my Department I have the highest tribute to pay to your energy and enterprise and usefulness. I am told that you add to your numbers 20 per cent. per annum—almost as good as a Marks & Spencer dividend!

I am told that your work is largely educational—well, heaven knows it need be. I am told you have discovered the method whereby the knowledge of practice and experience obtained by your older members is made accessible to the younger. That whole doctrine of carrying on the torch of accurate knowledge, scientific experience and engineering practice, is absolutely vital to a producing country. There is no index to knowledge, there never has been, and any system whereby you have your way, Mr. President, and form these centres and sections, wherever there is a great group of manufacturing interests in the country, is immensely to be commended because you put in permanent form the knowledge, the experience, the technique, that has been gained sometimes by scientific methods, sometimes from the rather cruder school of "trial and error." I won't attempt to make any suggestion as to the proportion in which science on the one hand or "trial and error" on the other are blended, but in my opinion the "trial and error" predominates.

The information given to me is that your machine tool industry has obtained a well-defined position and that you have gained a feeling of confidence through the protective duty of 20 per cent. and through the licences of the machinery which cannot be built here. The combined effect of these two systems—the 20 per cent. wall and the permission to bring anything that cannot be made here—has produced, I am told, a feeling of stability within your ranks. I am

glad to pay tribute to that. Also, I cannot proceed without saying something of the magnificence of the re-establishment of the machine tool exhibition at Olympia.

Gentlemen, you have the art of inspiring in the mind of everybody who comes in contact with you the necessity to remember elementary rules. Has not Hutchinson invested your funds in $2\frac{1}{2}\%$ Consols? Did he not do so when they were at a figure of 76? Are they not now over 91? Isn't that almost as much expansion as the average tolerance which you allow?

Mr. President, we cannot, in talking of an Institution of this kind, omit to mention the fact that you have decided, by deed poll or some other method, to add to yourself an additional Christian name. I am told that you are to be known in future as Sir Walter "Bradshaw" Kent because of the fact that you visit more places to the month, more centres of industry to the week, than Bradshaw's time table can keep up with. Your President, I am told, has established in his first year of office a record which it is quite impossible to surpass and very difficult to imitate. I am told that in the last few weeks he has acquired the almost ministerial habit of bobbing up in a different centre night after night—and I ask you, sir, with your experience of England, who could visit Leicester, Southampton, Manchester, Newcastle, Edinburgh, and Glasgow, and look so well as you do? With all these trials and tribulations your President manages to be urbane, efficient and punctual, and to serve your Institution well.

I thought that anybody who produced anything nowadays ought to be at a discount, but I am told that the production engineer who converts the blue-print into something that either works in the typical British way too long or else does not at all (they both have their drawbacks) may in time find the half-way house, that you will really build a pump that wears out in three years instead of the one that lasts for life and prevents your ever selling a replacement. Gentlemen, quality is a magnificent thing, but length of life can be shortened without any interference with the essential product and it is no good, in a world that does not want a continually endurable article, insisting on making that and making none other. We lose orders by hundreds of thousands of pounds every month of the year because we persist in only making the one standard when there is a world that calls out for more standards than that one; and if amongst your many "synthetic compounds," your "uses of overhead expenditure," your "unusual production methods," you may hit upon the helpful one for this country, then will your Institution add another page of glory to its name.

It is because in all seriousness I desire to pay my official tribute to your Institution, and because I enjoyed coming, that I ask you to be upstanding and drink to the toast of "Yourselves," this

Institution, and couple with it the name of your ever-popular, your most efficient, your supremely active President, Sir Walter "Bradshaw" Kent.

Sir Walter Kent, C.B.E., President, responding to the toast, said: It is no easy matter to follow an orator possessed of all the charm, of all the figures of speech, that Dr. Burgin has. I have heard him make many speeches and never have I begun to be bored on any occasion—but I do think to-night that he has stretched the "tolerances" of which he spoke rather too severely when he was good enough to refer to me. I have done very little compared with what I feel should be done for this Institution—in the good purposes of which I have such intense faith. I would like to say to Dr. Burgin how very greatly we are indebted to him, busy man as he is, sparing time to come here and help us on our way with a friendly push. There could be no more appropriate representative of any section of British public men than the Minister who stands for the furtherance of British trade, because it is our duty as production engineers to provide in the most efficient way that is possible those goods which it is Dr. Burgin's duty to help to distribute all over the world. And well he has done that. For the first time certainly for many decades we have found a Government that is endeavouring to help the trade of Great Britain rather than, as has happened so often in times past, a Government that has let any legislation pass no matter what hindrance it caused to the real interests of England's industry.

That is a wonderful change, and we see it in the returning tide of prosperity, in the greater number of people employed; we see it in that magnificent exhibition of machine tools that is at Olympia, which probably would not have occurred if it had not been for the faith given to that industry that it can pursue its lawful purposes without fear of being cut to pieces in price by foreign competition.

Referring to the work of this Institution Dr. Burgin mentioned the youth of the Institution, and I would submit that one of the extraordinarily hopeful features that we find in the young men and many of the young women of to-day is the eagerness with which they pursue studies that are likely to help them in taking and playing their part in the productive work of the country. I have had the opportunity of visiting a number of centres, and I have been struck by the tremendous number of evening pupils that are attending the technical institutions all over the country. In a place like Leicester, for instance, with a population of something like 180,000, there are no less than 4,600 pupils attending the technical institute, of whom over 4,000 are evening students. It means much to resist the lure of the cinema, much perhaps to resist the more healthy occupations of cricket or tennis. To go after a day's work and devote hours to technical instruction indicates that the youth of

our country have a genuine desire to play their part in saving her.

Now, gentlemen, to those studies I conceive it to be the privilege and work of the Institution of Production Engineers, by the educational advantages that they offer, to put a spear-head to the weapons with which the technical institutions of the country arm its youth because the Institution of Production Engineers is able to lay before its members, its graduates, the intrinsic knowledge of particular trades that has been evolved by experience—that in some cases is almost the result of heredity, where you find father and son practising some very difficult cult in a works and achieving a degree of success in a process that has been thought unobtainable—all that knowledge is being passed on and given as the spear-head to the training that they have shown themselves so ready to get.

Therefore, fellow-members, does it not behove us to bring that information within reach of those people who are so ready to accept it? You cannot expect young men to travel thirty or forty miles after a day's work, to sit for two or three hours listening to lectures or taking part in debates, and then to travel back those thirty or forty miles and to be as fresh as paint the next morning. We must do all that we can to bring it to them, if we believe, as I hope all here do believe, that our Institution has a real and important part to play in the welfare of our country. And think of it—it is production that is the very beginning, the very root of our industries, and upon that which we produce depends in the long run the whole sources of revenue, the whole prosperity of Great Britain.

MR. T. FRASER, Chairman of Council, in proposing the toast of "Our Guests," said: My very pleasant duty to-night is to propose the toast of "Our Guests." I might say that I only hold this position due to the indisposition of Sir Alfred Herbert, one of our Past-Presidents, who unfortunately is unable to be with us. I knew nothing at all about this until I arrived, so I hope you will excuse any mistakes I may make.

When I look round here this evening and see everyone's happy face it seems to me that this is really indicative of the present position of industry. Undoubtedly business is on the up-grade, and I sincerely hope it will continue so. I think perhaps some little part of that is due to the effects of a number of our distinguished guests who are here to-night. I think in their particular sphere they have played no small part in the improvement of industry of this country. Two years ago I happened to be in the United States. I saw the position over there and I was very astounded indeed. I thought we were badly off here, but those who have not been to America recently can take it from me that they are very much worse off than we are. I met several big industrialists there and they criticised us very severely, but I see that America is now following British systems, both nationally and industrially.

We have with us to-night, Dr. Burgin, Parliamentary Secretary to the Board of Trade, whom you have heard, and I think we owe him a very great debt of gratitude for coming along and giving us such an entertaining speech. We also have one of Dr. Burgin's right-hand men, Mr. Morgan. We have ex-Provost Lang, who is to reply to this toast. We also have a member of our own Institution, Mr. Pomeroy, who is this year's President of the Institution of Automobile Engineers. There is also Mr. le Maistre, Director of the British Standards Institution, who is co-operating very closely with us on standards. We have many other distinguished visitors also, from home and abroad. I would like to say now, gentlemen, on your behalf, that we extend to Our Guests a very hearty welcome, and we are extremely grateful to them for coming and adding to the prestige of our Institution. It only remains for me to ask you to fill your glasses and rise and drink to the toast—"Our Guests."

Ex-Provost W. B. Lang, J.P., responding to the toast, said: Mr. President and Gentlemen: It is difficult for an ordinary engineer to speak after such a magnificent address composed of humour and seriousness as that to which we have listened to-night from Dr. Burgin. I do think it is one of the finest after-dinner speeches I have ever listened to.

When I received the invitation to your dinner I thought "Now, here's an old boy, President of the Machine Tool Trades Association, who has a great deal to do with the Olympia Exhibition. The Institution of Production Engineers are going to give him the honour of asking him to their Annual Dinner." I accepted. Shortly afterwards I got a note asking if I would reply to the toast of "Our Guests," and I am quite sure that Mr. Hazleton is one of those wise gentlemen who knows that if he had sent that request along with his invitation the great majority of people who are asked in this way to speak find that they have previous engagements. I quite frankly say, however, that I did not have a strong feeling of this kind because I knew that I was coming amongst some of "my ain folks," although I should have enjoyed the dinner better had I been allowed to sit amongst you listening to the other speakers.

I look on your association as an institution that has started in a humble way and probably had its difficulties like almost every other institution of its kind; but it does seem to me that you have overcome your difficulties; you have got to the top of the hill and have reached a highly successful position. I am perfectly satisfied, Sir, with what I have seen to-night, and from what I have heard to-night and from what I have read in connection with your Institution that you have come to stay. Those of you who were at the beginning of this association's work must feel extreme gratification. I remember a very simple little story which I think is particularly

applicable to an occasion of this kind. An English gentleman was in the Highlands and as he walked along a country road beside one of the Scottish lochs a little boy sat by the roadside, crying very bitterly. Beside him lay a beautiful Scottish colly-dog, quite dead. The little fellow was crying his heart out. Along came another little chap, whistling like a tom-boy, and he said : " What are ye crying for ? " The little fellow, rubbing his eyes, said : " Och, my dog's dead." " Your dog's dead—what does that matter ? said the other. My grannie died last week and I never shed a tear." But the poor little chap replied : " Ay, but you did na bring up your grannie from a pup."

Now, gentlemen, those in your Institution who have been responsible for its initiation must have tremendous satisfaction that you have now reached the stage not of a puppy-dog but of a full-grown mastiff, and you are going to play your part in the development of the engineering of this country. I could not help thinking that you are responsible for results. There would have been no race to Australia with those magnificent aeroplanes without the production engineers—that is an absolute fact. There would not be, to-day, the same marvellous results from motor-cars. Any man who is an engineer and who does not take off his hat to those little eight h.p. cars that run day after day, hour after hour, at 3,000 revolutions per minute has no conception of the problems of engineering.

I myself have had a curious experience. Since 1915 it has been my duty to travel almost weekly between Glasgow and London by a sleeping car, and one day a gentleman said to me : " You must have travelled a long distance." A rough calculation proved to me that I had travelled in a sleeping-car between Glasgow and London and London and Glasgow. a distance equal to 25 times round the world. Now that is a long distance, once round the world is 24,000 miles, and never once during that time has the train been stopped by anything going wrong with the locomotive. That is a tremendous tribute to the engineering of this country. I have no hesitation in saying that a great proportion of the success of those products is due to the gentlemen surrounding these hospitable tables.

Let me give you just one other illustration—something that contributed to world history. It took place a short time ago on the Clyde. Some of you may have been present at the launch of the *Queen Mary*. The length of that ship is only a few yards less than the width of the river. When that ship was launched it must have staggered those who were not engineers, although it even staggered the engineers, to see that monster leviathan pulled up within a few yards of the other side, and immediately a more wondering sight met the eye. A half-dozen cheeky little impertinent

tugs, pigmies of the shipbuilding world, took charge of that leviathan, and within a very short time it was safely docked where it will be finished and brought to a condition when it can have its maiden voyage.

I introduce that for this reason. You gentlemen here are the leviathans of the engineering world. You conduct the aeroplane manufacture, the electrical manufacture—all the general engineering of the country. We who are represented at Olympia at the present time are the pigmies, the little tugs. Without the little tugs you, the leviathans, are of absolutely no use. I suggest that as many of you as can come should spend as long as possible at Olympia, for we have presented there the finest exhibition of machine tools that has ever been shown in the history of the world in any country. I offer to you Mr. Chairman, and to you, gentlemen, our very hearty appreciation for the magnificent dinner which you have given us and our sincere thanks for the splendid enjoyment we have had by our association with you round these hospitable boards.

Mr. L. H. Pomeroy, M.I.P.E., M.I.A.E., proposing the toast of "The President" said: Mr. President and Gentlemen—I have the greatest pleasure in proposing the toast of "The President." You know far more about your President's activities than I do. You know how he has devoted himself to your interests and to everything concerned with the growth of this Institution. You know how close it is to his heart, how sincerely he believes that this Institution is a vital factor in British industry. Dr. Burgin has told you the number of occasions upon which Sir Walter has turned up at your meetings and taken not only an interest in them but I am sure a very important guiding interest in them. It is no small thing for an institution of this kind to have at its head a man of the calibre of Sir Walter Kent, with his vast experience of business, and what is more, his vast experience of human nature.

There are a great many men in this country—and I do not except production engineers—who turn their eyes westward and look across the Atlantic and judge what is happening in production by what is being done in America. There is no falser judgment that you can find. In America a nation has been sacrified for a cheaply produced motor car. Never forget it. That is a very serious matter. Dr. Burgin told you just now that it is your duty to make things which do not last too long.

Unfortunately, they have not gone quite far enough. As you know, five years ago something happened on the New York Stock Exchange. People who were millionaires on Thursday found themselves paupers on Friday. The result of that was that they said "Will our car last another year?" And it did. This halved the output and, what was worse, they said will it last a further year, and it did. That has produced such a reaction in America

that no one who has not lived there, as I have, can picture the dislocation and the distress and misery which has occurred in America through this worship of the golden image of production.

You are production engineers. I am a prediction engineer. Your business is to make things cheaper and use less men hours and to put men out of employment. My business is to make things better, to use more men hours; to put them into employment. I know your reply. "If you use less men hours and increase demand we then re-employ men we have dismissed." That may or may not be. It depends on the rate of expansion of industry in general. There is a lot to be said for considering very carefully the net effect. Believe me, the question of the employment of people is something which had better not be predicted upon the theory that labour *displacement* necessarily means increase of employment. This country has gone a long way in the last year, but it has still got a long way to go.

In so far as your own Institution is concerned I hope that in the near future you will begin to ask your members for professional qualifications in terms of written examinations. I know this business of examination qualifications is a very difficult matter, to say aye or no about, but I am quite sure that the man who has been trained academically to some extent and has passed examinations has, on average, a better approach to the many problems of engineering than he who has not. We have heard that membership of this Institution is expanding at the rate of 20 per cent. per annum. I am the President of an institution where the membership is increasing at the rate of two per cent. per annum, and we are proud of it.

In conclusion, I wonder how many members of institutions in general and our own in particular realise the work put in by their President. In Sir Walter Kent we have a President whose time is more than fully occupied by the ramifications of his own business. His leisure is desperately hardly earned, yet in some miraculous way he finds the time to be with us on all occasions, important or otherwise. Gentlemen, Sir Walter Kent.

SIR WALTER KENT: I am deeply touched by the kind way in which Mr. Pomeroy has proposed my health, and am most grateful to you for the warm manner in which you have received that toast. At this hour there is no time to comment on Mr. Pomeroy's references to the state of industry in the country and whither we may be led by excessive production, but much of what has been said gives cause for very careful reflection. One lance I must break with him is that this Institution does set efficiency in the highest of all places in the objects which it seeks to attain. Mr. Pomeroy suggested that it was speed of production rather than excellence, but I would assure you, sir, that it is excellence that we place first and speed

next. The time element is one we can all take to heart ; it is one of those very puzzling and annoying things.

With regard to myself, I should be lacking in modesty if I did not put in a very strong disclaimer for the kind words said. I happen to be in the position of your President and I have done what every one of you would have done given the same opportunity—that is, to further the interests of the Institution we have so much at heart. I thank you very much indeed, and wish you good night.

A METALLURGICAL SURVEY OF ENGINEERING MATERIALS

Paper presented to the Institution, Birmingham Section, by Josiah W. Jones, M.Sc.

THE Spirit of Production is much too etheral to be confined within the boundaries, wide though they be, of engineering practice, but it has permeated the associated science of metallurgical practice with far-reaching results.

The task of the older metallurgist was a comparatively simple one, to cast and then forge, or hot and cold roll as required to the semi-finished state. This product, the engineer took over, to make with lathe and file as good an article as the raw material justified. Metallurgical control was limited to the occasional chemical analysis of a "sample." Looking back from 1934 the success attendant on their leisured efforts is often surprising, and sometimes discomforting. If, however, the modern trials are greater, so are the triumphs.

The demand for increased output and decreased cost of operation has been met in modern metallurgical practice by extensive electrification and ingenious mechanisation of operations in order to render them fully or semi-automatic and continuous. These changes have involved a detailed study of the conditions of heat development and transfer, and of the chemical and physical reactions taking place in the material during the processes. Such knowledge gained is now permitting a close control at each stage, and is found to yield a more uniform product with improved or new mechanical properties.

It is interesting to compare the old two-high pull-over rolling mill, manipulated by hand, with the modern four-high reversing mill, electrically operated and manipulated, or the old coal-fired annealing oven and adjacent pickling and washing vats—all operated by hand, with the latest type of continuous process using an electric furnace having automatic temperature control, and all operations mechanical and continuous. The advantages which this new spirit of engineering has conferred on metallurgical practice has, in turn, produced for the engineer materials of construction with unexpected properties and reliability.

The continuous furnace has done much more than simplify the problems of handling. By co-ordination of the rate of travel of the

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November 21st, 1934.

work through the furnace, and close control of the temperature of adjacent zones in the furnace, it has been possible to control, with efficiency and economy, the rate of heating, the duration of soaking at maximum temperatures, and rates of cooling. These factors are all vital to the production of maximum values and uniformity in the whole section from day to day.

The modern engineer seeks four outstanding qualities in his materials of construction :

(1) High strength to weight ratio.
(2) Shapeability—i.e., free cutting or suitable for die-casting, pressing, or stamping.
(3) Permanence.
(4) Standardisation of surface, dimensions, and properties.

High Strength to Weight Ratio.

A survey of existing materials is interesting and leaves an open choice, since the heavier steels and light alloys have similar relationships of strength and weight. Efforts to decrease the weight to strength ratio will be directed along two distinct paths : (*a*) to raise the elastic limit of the material, or (*b*) to find new materials with lower specific gravity and the necessary relative strength. Both methods are being followed with success.

Metallurgical research on alloy steels and their heat treatment. Some details of these will be discussed later. Steels are being produced with elastic limits approaching 100 tons per square inch compared with 13 tons as the value for an ordinary 0.25 per cent. carbon steel. The ratio of elastic limit to tensile strength is also increased.

Except for a few details, these alloys cannot be regarded as new, since they have played their part in special construction for a few years, but what is new, is that the full advantages of their combined properties are becoming more widely recognised, and they are taking their place in production. It is usually considered that cutting speeds are slower with alloy steels, but when higher tensile strength is the major consideration, some alloy steels offer good machinability. The premier position of the 3½ per cent. nickel 0.30 per cent. carbon is worthy of notice for strengths up to 76 tons per square inch. It must be recognised that each material has its own technique for cutting speeds, and that a change of material without change of method may not yield the best results. These facts are now often appreciated by the suppliers who investigate the best methods, and will gladly pass on to users such details as speed, feed, depth, and tool angle.

In order to give some impression of the weight-saving properties of these steels, Messrs. Samuel Fox have prepared three tensile

test pieces, each having the same yield load of 17 tons. The diameters are as follows:

Mild steel	1.124 *in.*
Tormanc Major (Mn.Mo.)	0.751 *in.*
Tormol (Ni.Cr.Mo.)	0.565 *in.*

The centre test piece may be classed as a "low alloy" steel. Two examples will serve to draw attention to this type of steel which is much cheaper than usually obtains for alloy steels:

Steel: *Carbon,* 0.30. *Manganese,* 1.75. *Molybdenum,* 0.18.
Section: 4¼ *in. diameter.*
Treatment: Water hardened from 850° *C., tempered* 650° *C.*
Properties: Tensile strength—52 *tons per square inch.*
Yield point—43 *tons per square inch.*
Elongation—23 *per cent. on two inches.*
Impact Izod—80 *ft. lbs.*

Steel: *Carbon,* 0.15. *Manganese,* 1.3. *Vanadium,* 0.10. *Silicon,* 02.0.
Treatment: As rolled.
Properties: Tensile strength—40 *tons per square inch.*
Yield point—29 *tons per square inch.*
Impact Izod—20 *ft. lbs.*

The properties of the latter steel in the "as rolled" condition made it attractive for structural purposes.

The advantages of alloying practice are not only to be found in the improved mechanical values of the annealed steels, and increased range of properties by heat treatment but also in the nearer approach to uniform properties in parts of varying thicknesses, and the combined effect of higher elastic limits without decrease of shock value.

Alloys with low specific gravity. Magnesium alloys would appear slightly superior on the basis of strength-weight ratio, and this justifies the increasing use of these alloys for crank cases, gear cases, brackets and housings and covers in general, in high speed blowers and super-chargers. This trend will continue now that manufacturing difficulties have yielded to experience. The casting in Elektron for a crank case of a large Diesel engine will weigh six cwt. compared with 10 cwt. in aluminium alloy, but the magnesium alloys are not yet used for parts subjected to alternating stresses at higher temperatures. Alloys of aluminium have well established their places as a constructional material, but it is interesting to note the gradual improvement in mechanical properties as a result of enterprising research. Such rarer metals as titanium and cerium have been called in to contribute their quota to what Nature can achieve by scientific combination.

That these strong light alloys play a decisive part in the construction of trans-continental air liners and trips into the stratosphere is appreciated, but they are also gradually displacing the less efficient materials in all forms of transport constructions for frames, panels, and general fittings. This practice will continue as the designer is able to dispel the inherited complex that safety depends on weight and thickness. Lower bearing loads and smaller forces of inertia mean reduced power requirements.

A further structural property not shown in the previous consideration of strength-weight ratio, is that required by the form factor. An aluminium bar of equal stiffness to that of a steel bar of similar geometric cross section would have 1.14 times the strength, and only .614 times the weight ; or comparing two such bars of equal weight, the aluminium bar would have 2.37 times the tensile strength and 2.65 times the stiffness (the property of resisting stresses in the elastic range with only small deflection). The limitation of thin steel is met by the design of tubular structure and cross bracing, and the final choice is still an open one. In illustration of this, it is interesting to compare two modern trains, both American, driven by Diesel engines. The one complete train of three coaches weighs 85 tons in aluminium alloys, and the other weighs 95 tons in stainless steel. A train of similar size but usual construction will weigh about 200 tons.

A Press report of October 26th, 1934, reads : " A new aluminium streamlined Diesel-engined monster has just broken the world's speed record held for thirty years by Britain—102 m.p.h. from Paddington to Plymouth in 1904. The Diesel reached the amazing speed of 120 m.p.h. on a journey from Los Angeles to New York, a distance of 3,334 miles which it covered in fifty-six hours and fifty-six minutes at an average speed of 58½ m.p.h." vide *Daily Express*.

Shapeability.

If the term cannot be found in the Oxford dictionary, it can at least be justified by the fact of it being much more useful than many new words which find their way into general use. The production engineer will require in his ideal material, that the one and same metal shall possess the contrary properties of plasticity and strength—the former to permit ease of shaping by stamping or pressing, and the latter to give the necessary strength in service.

The nearest approach to such an ideal were the medium and high carbon steels, but cost and relative hardness in the " soft " condition detracted from their use as structural materials. Their value as cutting tools resulting from hardening heat treatment, is age long, and requires no comment. The 40-ton steels with their intermediate carbon content are well-known for their combination of shaping

and heat-treated properties. In the early part of the present century, two metallurgical discoveries were to make a revolutionary contribution to the practice of engineering. After many years of methodical work, Taylor, an engineer, and White, a metallurgist, working together in America, perfected a discovery which was to bring the greatest change into engineering practice, since the days of Watt—the production of high speed steel. This alloy, *hardened* on tempering, a reversal of all previous conceptions of the heat treatment of steel. The super-hardness of these steels completed the quest of the original workers—an increase of some hundreds per cent. in cutting speeds, the taking of heavy cuts, and as a result of resistance to wear, rendered possible the array of tools in a multi-cutting set up. This type of production was not their only service to engineering, for the development of temper hardness introduced a new phenomenon to be explored.

The second discovery was that of an alloy, Duralumin, by Wilm. Not only was this a non-ferrous alloy which could be hardened by heat treatment, but it also produced the further surprise of a metal which *softened* on quenching from an elevated temperature. Here was the dream of every engineer being fulfilled—a material which could be obtained in both soft and hard states—the former by quenching from a dull red heat 520° C., and in this condition—

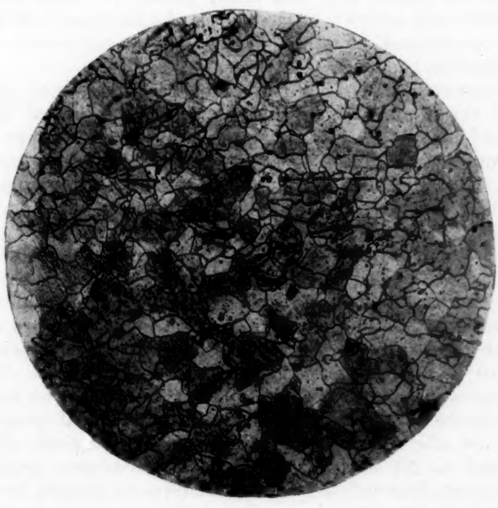

FIG. 1.
Microstructure of iron × 100.

Brinell 70 (best brass 60) can be shaped. When the operations are complete, increase in strength and hardness is obtained by standing at room temperature (ageing) or reheating to such low temperatures (150° C.) as would not alter dimensions or surface. In the completed form this produces : Hardness, 105 Brinell ; tensile strength, 25 tons per square inch.

Metallurgical research into the mechanism of these changes, i.e., the production of relative softness by quenching, and hardness by reheating, has, during the last twenty-five years established a relationship between these mechanical properties, and the crystal structure and atomic arrangements in the metal.

The appearance of an equilibrium diagram and photomicrograph to illustrate the constitution of a series of alloys, is now so frequent in the literature of engineering, that it would be interesting and helpful to attempt some explanation of the structural mechanism controlling these changes in mechanical properties as far as it is conceived by metallurgical theory. That metals are all crystalline is well known, but that all crystals are brittle by nature is quite an erroneous conclusion. All pure metals are agglomerates of small crystalline masses which are quite plastic and "shapeable." The addition of another metal or non-metal such as carbon or silicon, tends to increase the strength of the individual crystal grains which constitute the mass, and also often forms, in some proportion, a new constituent which is in most cases of a hard and brittle nature. This new constituent, by offering a resistance to movement, strengthens and hardens the mass as a whole.

A photomicrograph is a highly magnified section of such a material, and from the appearance of this section, the nature of the metal in the solid may be deduced. The crystal grain structure of a pure metal is revealed by its cross section (Fig. 1), and the microstructure of a steel in the annealed condition is seen to be the same type of mass, strengthened by the presence of the harder, dark masses of pearlite (Fig. 2), which raise the tensile strength of the agglomerate from 18 to 40 tons per square inch. Thus most materials of construction which the engineer receives—rough shapes in cast iron, black bar of alloy steel, or sections of bronze ingot, are all made up of these small crystalline grains, and small masses of hard constituents. The mechanical properties of the whole are dependent on the nature and distribution of the microconstituents. Since all shaping operations, both hot and cold, have an effect on the nature and distribution of these particles, the mechanical properties of the mass are also affected. Machining has a minimum effect, and it is limited to the surface. Since each constituent grain of the metal is a crystalline substance, it will deform on shaping by slipping only in certain directions, hence the maximum resistance to movement—that is, greatest hardness, coincides with the uniform

distribution of the finest sized particles of the hard material. Any means by which the hard constituent can be uniformly distributed, will bring the material into a stronger and harder condition.

Referring to duralumin type alloys, the structure of this alloy at ordinary temperatures is seen to be composed of ductile crystal grains, and relatively large masses of a hard chemical compound of copper and aluminium. As the temperature of this alloy is raised, the hard compound is reduced in proportion, since its solubility in the *solid* crystal mass increases from 0.3 per cent. copper at room temperature to 5.6 per cent. at 548 degrees C. The nature of the microstructure at this temperature, when all the hard constituent is dissolved, is of the same type as a pure metal. If now the alloy be quenched in water from this temperature, there is no opportunity for the hard particles to form and precipitate in the crystal structure —in the same way that there is no opportunity for passengers to alight at a station, if the train passes through without stopping— and the crystal structure retains its plastic nature. In this state the metal is suitable for shaping. On standing at room temperature for some hours, or in shorter times by slight reheating, the hard particles of compound are precipitated in such fine state of division as to confer maximum hardness on the structure, by offering uniform interference to crystal movement. The fineness of this structure

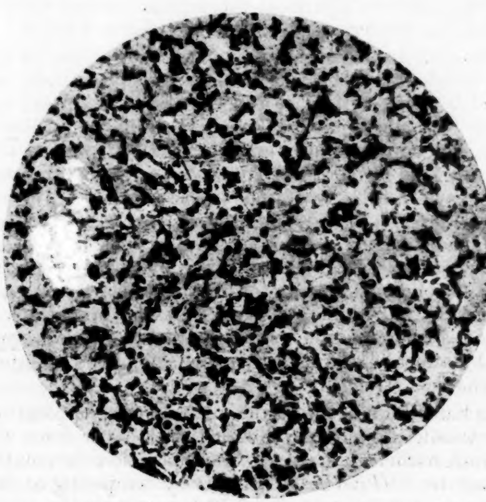

FIG. 2.
Microstructure of steel, 0.25% Carbon × 100.

is such that the particles cannot be detected by the microscope. On further tempering, the particles collect into larger group masses, and the metal softens to its ordinary annealed properties. Thus the alloy is obtained in its softest and most shapeable condition by quenching in water from above a critical temperature, and on reheating acquires an increased hardness with associated tensile and compressive properties. Thus with combined shaping and heat treatment processes, the alloy is prepared—soft for shaping, and strong for service. It will be recognised that this is a complete reversal of the time-honoured treatment of steel, which is rendered hard by quenching, and softens on tempering.

A world-wide intensive study of the structural changes associated with the hard and soft states, has been pursued by means of pyrometer, microscope, X-ray tube, and resistance bridge. It has been confirmed that these useful properties of hardening and softening by correct alloying and simple heat treatment, are common to most metals, and the mechanism of the changes is capable of this same simple explanation.

Research enterprise of the Imperial Chemical Industries, Limited, under the direction of Dr. Brownsdon, has recently justified this conclusion in the case of copper alloys. That copper could be hardened and tempered like steels, was, until recently, regarded as a product of mythology, but metallurgical theory has insisted that it should be possible, and modern research methods have done it.

Brass has long held a place in engineering practice, in spite of its moderate tensile strength of 15-30 tons per square inch, because of the ease with which it may be rolled, pressed, stamped and drawn in the cold. The addition of nickel and aluminium to displace some of the zinc, e.g., copper 65 per cent., nickel 13.5 per cent., aluminium 1.5 per cent., zinc 20 per cent., produces an alloy, the strength of which may vary from 24 to 57 tons per square inch. The advantage of the new alloys is found not only in the increased mechanical values of the finished section, but also in the *INCREASED FACILITIES FOR SHAPING*. An ordinary brass may be drawn from the soft condition and its tensile strength raised as a result of the operations, to 30 tons or more, but the operations must be designed to reach completion before the cracking stage is approached. To soften by annealing for a further operation loses a major portion of the mechanical strength.

By using Kunial brass, the hardening from the complete operations raises the tensile strength to 40 tons for 50 per cent. reduction. In this work-hardened state, if the operation is complete, the product may be *SUPERHARDENED* by tempering at 500°C. for two hours, to a tensile strength of 50 tons per square inch. If the operations are not complete the work may be resoftened and after

the completion of all operations, tempered to a strength in excess of 36 tons per square inch. The whole range of properties of copper, which by the alloying additions can be softened by quenching,

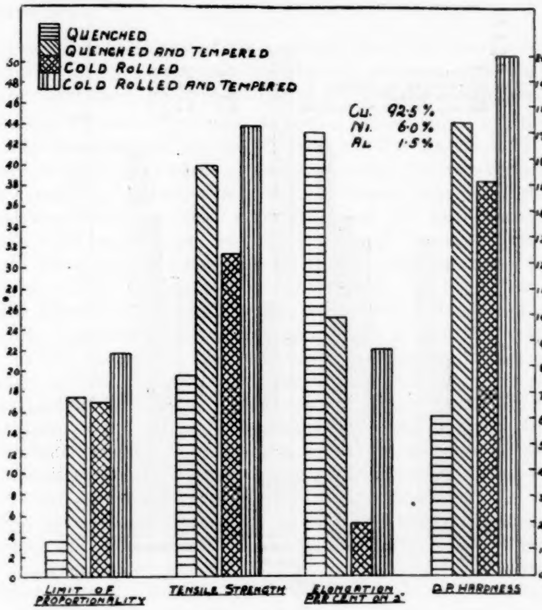

FIG. 3.

shaped and temper hardened, are shown diagramatically in Fig. 3, and similar properties of brass in Fig. 4. As a guide to the composition these alloys have been called " Kunial " by the makers.

In all cases where strength must be sacrificed to allow final shaping, for example : spring washers, small angle supporting pieces, all the desired shaping qualities may be retained and increased strength imparted by a final heating and quenching. The process is being extended to all the copper rich alloys. It is logical to anticipate that alloys of such metals, as zinc, tin cadmium, and even lead, will contribute to the practice of engineering materials with mechanical properties, and facilities for shaping, hitherto unexpected.

The engineer has long been between the Scylla and Charybdis of increased strength at the expense of shaping powers, i.e., high yield stress and small elongation per cent. These limitations have now

been largely removed by metallurgical research, which has revealed the relationship between the microstructure and the mechanical properties, and the structural changes which take place when alloys

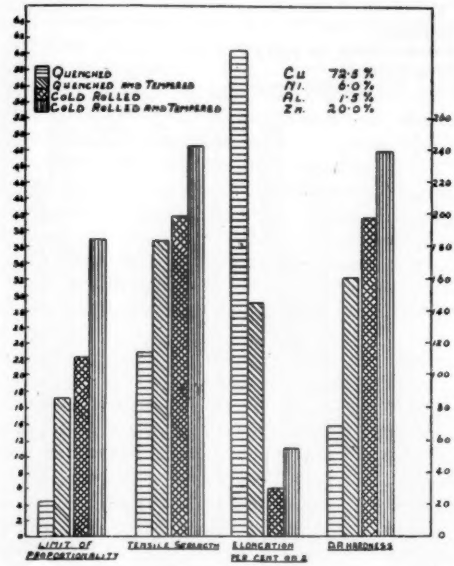

FIG. 4.

are made. This alloying practice no longer depends on trial and error, but conditions can be stated for the improvement to be gained from the strengthened matrix of crystalline grains of solid solution, and in addition, the conditions which will promote softening by quenching and temper hardening, a property which depends on the presence of hard compounds, which have an increased solid solubility in the matrix at higher temperatures, and when quenched, precipitate in a state of fine division on ageing or tempering.

The less common metals like nickel, chromium, and molybdenum, have been brought into everyday practice, and such rare elements as cerium, titanium, tellurium, have been utilised. From the equilibrium diagram the possibilities of a range of alloys can be anticipated, and mechanical properties estimated within close limits.

The universal nature of the phenomena among metals has given an increased range of usefulness to all metals and from a familiarity

with these properties, the engineer will be able to choose, without compromise, the best alloy for the particular purpose, combining strength, stiffness, weight reduction, and ease of shaping.

Permanence.

The charge on industry of replacement, has long been recognised. It becomes necessary from two broad causes: (*a*) Failure of defective material; (*b*) Weakening of section due to corrosion.

Failure of Defective Material. Ignoring before this Institution the possibility of unsatisfactory design, failure of the material will be due to incorrect heat treatment, or heterogeneity of the structure. The former should not occur with such complete service available from the technical staff of most suppliers, and the automatic control available with many types of heat treatment furnaces. The latter, chemical and physical heterogeneity in the material, have been the subject of considerable metallurgical research, resulting from which, attention has been directed to the important influence of melting conditions, pouring temperatures and practice, and the nature and design of the mould, on the structure, and hence on the uniform properties of the material. Particular reference may be made to the production of sound metal, i.e., freedom from blow holes. A limitation to the use of aluminium alloys has been the existence of a pin hole porosity, producing a reduction of some 50 per cent. in the tensile strength of a sand casting, with corresponding decrease in the other mechanical properties. This problem has received attention by research workers. The origin of the defects have been discovered and correct melting and casting technique drawn up. Sound castings which justify confidence can now be obtained from accredited sources. Dr. N. Allen, of Birmingham University, has directed attention to the major influence of hydrogen gas in the furnace atmosphere, and hence in the metal, on the causation of porosity in copper rich alloys, and has demonstrated the influence of the mould used, on the nature and distribution of this porosity.

The use of the X-ray spectrometer has yielded considerable additions to our knowledge of those structures of metals which are too fine to be resolved by the microscope, and, in particular, concerning the variation in the crystalline arrangements of the atoms when metals are alloyed together. More recent uses of this instrument have not only been in the detection of internal cavities and defects, but also on the mechanism of deformation and changes in structures during shaping.

All these steels are air hardening, and give a useful range of physical properties, the following being obtainable in the air-hardened and tempered condition, which is the best condition from a corrosion point of view.

Grade	C.	Cr.	Ni	Max. stress tons per sq. in.	Yield point tons per sq. in.	Elong. per cent.	R. of A. per cent.	Izod ft. lbs.
10	.10	12/14	—	70/40	60/30	12/40	40/70	20/100
11	.16	12/14	—	95/45	90/40	10/30	12/70	40/120
12	.22	12/14	—	100/50	95/45	10/30	12/65	15/70
13	.35	12/14	—	110/50	100/45	4/30	4/50	5/30
18	.10	18	2	65/45	50/30	20/30	55/60	60/80

FIG. 5.

Directional properties in a material have always constituted a problem in engineering, and necessitated specified properties in transverse and longitudinal directions. The impact value of a rolled steel often varies with the direction of testing, and variations in elongation and bending properties are found in sheet metal. A gradual change in the nature of the structure of a metal followed by a superimposed directional effect, are shown by the X-rays when a metal is cold rolled. Though much remains to be done, the available data would show promise of the use of such fine scientific control of manufacturing methods, to produce a material which is quite uniform in its properties.

The elimination of defects from the original castings, rolling practice designed evenly to distribute the " work effect " and furnace practice using control of temperature and atmosphere so that there is no scaling, all combine to manufacture continuously a uniform product. Freedom from defects in the crystal structure means reliability and safety.

Weakening of Section due to Corrosion.—The use of stainless irons and steels is now becoming commonplace for domestic use, but the mechanical properties of these alloys, and their possible uses in engineering have yet to be fully appreciated. Increased mechanical values are available in air hardening steels (Fig. 5) which, in the tempered condition offer the best resistance to corrosion. Such steels have an increasing use in steam generating plant and power production.

A frequent cause of failure of steam valves is a leakage between the valve and the valve seat, due to the presence of foreign matter. The hardened stainless steel does not suffer indentation from this cause and, in addition, erosion does not take place under the action of high pressure steam. Such steels as No. 18 (Fig. 5) are used for feed check valves, injector cones, and turbine blading. Recent research has made these steels immune from weld decay by alloying with titanium or columbium in small proportion.

The early difficulties in machining and forming have been reduced considerably by research into the structural changes involved in both

alloying and heat treatment. It has already been shown that a malleable structure (solid solution) existing at high temperatures in Kunial metals and duralumin, may be obtained at room temperatures by quenching. Similar phenomena exist in alloys of iron, carbon, chromium, but the range of stability of the malleable structure may be brought down to room temperatures by the addition of the necessary proportion of nickel. Thus the alloy 0.1 per cent. carbon, eight per cent. nickel, 18 per cent. chromium is a solid solution, the hardening carbides being rendered soluble in the new matrix. The limitation to this softening by a change of composition is that these alloys are not subject to modification of properties by simple heat treatment, but they may be hardened by cold work in the usual way. The shaping qualities of these low carbon alloys are in strong contrast to the early stainless steels. Stainless irons have pressing and drawing qualities (Ericheon 17.0 mm. on 20 gauge) quite equal to best brass, and the following comparative properties:

	Yield point Tons sq. in.	*Max. stress Tons sq. in.*	*Elong. Per cent.*	*Red. in area Per cent.*	*Hardness brin.*	*Izod ft. lbs.*
Stainless iron ...	34.6	40.7	32.0	69.0	179	98
Best brass ...	6.0	23.0	75.0	70.0	46	45

More power may be required and some modification of tool design and pressing speed to obtain the best results. Stainless irons may be successfully formed by spinning. The higher carbon alloys stainless steels work harden at a much faster rate than the stainless irons, but the combination of higher yield stress with both elongation and shock value make an appeal to the designer.

Carbon 0.14, *Cr.* 14.9, *Nickel* 10.8, *cold worked to* 23 *per cent. reduction from half inch diameter.*

Yield stress	53 *tons per square inch.*
Maximum stress	63.2 ,, ,, ,,
Elongation per cent.	33
Reduction in area per cent.	62
Impact Izod	37 *foot lbs.*

Many amenities of the day which result from chemical engineering are indebted to these steels. Recent investigation into the causes of failure from fatigue of moving parts have directed attention to the part played by corrosive attack on the surface, as the initial cause of failure by promoting discontinuity of the crystal mass where the stresses are concentrated. These facts tend to stimulate the demand for corrosion-resisting material for highly stressed

parts. The relatively higher impact value of these steels at ordinary temperatures are maintained at lower temperatures, which are met at high speeds in the upper atmosphere.

Considerable advances have been made in rendering alloys of aluminium resistant to corrosion caused by atmosphere and sea water, both by alloying and surface treatment. M.V.C. alloy has mechanical properties in excess of B.E.S.A. specification. It may be cast, rolled, forged, drawn, spun, and stamped with much facility. It will resist over long periods the action of sea water, sea air, or oil, smoke, and wet steam up to temperatures of 82 degrees C.

The Birma bright series of alloys—aluminium and magnesium, have been successfully used for construction of the hull, frame, members, and most other parts of motor cruisers, without any special surface treatment.

The anti-corrosive anodic treatment of aluminium alloys is well known, and magnesium alloys can be protected to give good service in conditions occasionally corrosive, but coating with selenium film. (British patent 378,916).

Strength at High Temperatures. Demand for increased efficiency in power production has called for constructional materials with mechanical properties at increasingly high temperatures. Exhaust gases from the internal combustion engine are of the order of 800° C. as a conservative estimate, while superheated steam temperatures have risen to the order of 3,200 lbs. at 800° F. Early attempts by research workers to measure the tensile strength of steels at high temperatures, gave curiously inconsistent results until it was realised how important was the time interval during testing. It was discovered that although a certain stress was required to produce fracture in a direct test, a much smaller load if left in tension would cause the test piece to gradually elongate and fracture. This property of deforming continuously in a plastic manner has been called " creep," and its recognition has added to the specified requirements of a constructional material. The rapid decrease in strength of ordinary steels above temperatures of 500° C. is alarming, but alloying practice has extended the relative benefits conferred on steels at room temperatures to higher temperatures also.

The designer must first assume a life for the structure, and then calculate the maximum permissable change of dimension. From working temperatures and " creep " data, the constructional material is chosen. In particular cases this material may be required to resist the stress which causes an elongation not greater than one hundred millionth inch per inch per hour.

Cast Irons. In no material are the changes due to metallurgical research, more surprising, than in cast iron. The statement to this Institution ten years ago, that automobile camshafts and crank-

shafts were being made in cast iron, would have been received with incredulity, and the use of a casting to displace a forging, would have been disturbing even to a metallurgist. Such is reported (*) to be the practice to-day, with a cast-iron containing nickel, chromium, and molybdenum, and for which the following properties are claimed : Tensile strength, 21 tons per square inch ; Brinell hardness, 300 ; torsional strength, 10 tons per square inch for four twist, and a fatigue strength equal to five times that of the equivalent carbon steel.

The old cast iron of eight tons per square inch and no shock value, has given place to a material with tensile strength of the order of 20 to 30 tons per square inch. Scientific alloying and casting technique have made these qualities possible in production. The cast iron which can be rolled, stamped, and pressed, is not yet, but the means by which such properties can be conferred, is much more than a speculation. It is a fair prophecy that only the foundry with technical knowledge and control of melting and casting practice will be able to supply the demand of the engineer, in the course of the next few years. As a reliable material of construction, it will probably replace steel in many places. To-day, the engineer may order from a progressive foundry a cast iron which can be hardened and tempered to give a hardness of 546 Brinell, and a tensile strength of 16.3 tons per square inch, or, a hardness of 332 Brinell, and a tensile strength of 29 tons per square inch. Where facilities are available for machining hard surfaces, castings may be made with a surface hardness of 400 Brinell, by adding five per cent. nickel. Such irons have achieved some reputation for cylinder liners, brake drums, and similar purposes. Should maximum surface hardness be required for crushing machinery, and parts subjected to severe abrasion a hardness of 700 Brinell may be obtained in an alloy containing 4.5 per cent. nickel and 1.5 per cent. chromium.

Standardisation of Surface, Dimensions, and Properties.

The production engineer has become an artist in standardisation, but he is limited by the extent to which the materials have qualities of permanence. Considerations of surface, which also involve fine dimensions, are related with structure and all that has been claimed for modern metallurgical practice in producing uniformity of internal structure, means also a uniformity of external structure. The " orange peel " effect in cold drawn brass, the wavy surface in cold drawn steel, or stretcher strains on the surface of steel sheet are all related to crystal grain size and shape ; the occurrence of these defects is decreasing, and should disappear.

Changes in mechanical properties of cold drawn metal with

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* *Machinery, Vol. 41, January 26th, 1933*

time (ageing) dimensional changes due to heat treatment processing or change of temperature in service, are the subjects of continued research. The old problem of clearance of the piston in an internal combustion engine is being solved by the combination of aluminium alloy piston and austenitic cast iron cylinder liner, each having chemical compositions controlled to give the same mutual coefficient of expansion with temperature. In this way clearance is independent of the temperature of the engine.

That these materials with their finely controlled properties are available but only at a prohibitive cost is a conclusion natural but not strictly justified.

Costs. Two facts militate against the adaption of new constructional materials ; the inevitable higher cost of the raw material and the possible development of unsuspected weakness, particularly brittleness, after putting into service. The former may be very misleading since the only safe place to cost is at the end of the assembly line. The volume to weight factor must be recognised. The cost of raw material for a particular section would be the same if made in :

Electron at 2*s.* 0*d. per lb.*
Aluminium at 1*s.* 2.6*d. per lb.*
Brass at 5.11*d. per lb.*
Malleable iron at 5.66*d. per lb.*

Incidental savings in other materials as a result of a lighter construction must also be considered.

Attention may be called to economies resulting from the use of high strength heat resisting alloy steels, often containing tungsten for dies, punches, and tools for hot shaping processes. Some results are seen from the following experience :—

Comparison of cost of alloy and carbon steel.

Initial cost of material	12 : 1
Tool, machined and prepared	4 : 1
Life	8 : 1
Saving in total cost	50 *per cent.*

Further economies follow from uninterrupted production.

That new alloys in service may develop a peculiar and unexpected defect is an ever present possibility, but the type of defect which is in any sense new is a decreasing probability, and only becomes a serious factor when service under new conditions, e.g. in Arctic Regions or the Stratosphere is demanded. A further reassurance is that the newer alloys owe their properties to crystallographic phenomena which is common to all metals and not to a feature, apparently peculiar to the metal. Full confidence, however, can only be given when all the structural possibilities of the series of

alloys, metastable and stable, that is, temporary and permanent, have been ascertained by metallurgical investigations.

By way of summarising this review it is of interest to note the part played by these modern alloys in bringing to such a state of perfection the new "child" of the engineer—the high speed Diesel engine

Weight/b.h.p. ratios are obtained of the order of 10 lbs. for transport purposes or 2.53 lbs. per b.h.p. in a British radial aero engine. Increase of speed at small increased cost is made possible by the weight reduction and heat dissipation conferred by aluminium castings. An interesting feature is the alternate choice made by different designers

PISTONS.—Y alloy. R.R. alloy. *Nickel Cast* iron body and Ni-Resist crown.

LINERS.—Steel. Nickel cast iron. Air hardening cast iron. Nitricastiron.

CRANKCASE.—Nickel cast iron Aluminium alloy. Magnesium alloy. Built up steel.

CONNECTING RODS.—Nickel Chrome steel Y alloy. R.R. alloy.

CRANKSHAFT.—Nickel Chromium steel.

EXHAUST VALVE HEAD.—Nickel Chromium steel, Ni. Cr. Iron alloy.

CYLINDER HEAD.—Nickel Chrome cast iron. Nickel steel.

BREACH END.—Nickel cast iron.

EXHAUST MANIFOLD.—Nickel cast iron.

STARTER VALVE AND BODY.—Ni-resist cast iron.

Bed plates, bolster castings, housings, covers oilsumps, and inlet manifolds may be made in aluminium or magnesium castings if reduction in weight is desirable.

The limitations of time for this paper are recognised and no detailed reference is made to bearing metals, super hard cutting materials and the expanding industries which depend on the electrical and magnetic properties of materials, but it must be realised that the research activities which have given such benefits to the production mechanical and structural engineer, have an equal share for all interests The production engineer is to be congratulated on his happy position as the agent whereby all these resources of Nature are made available to an ever-widening circle.

The author would disclaim any interest except a sense of gratitude to the following for data used in the illustration of this paper :—Imperial Chemical Industries, Limited ; Samuel Fox & Co. Ltd., Sheffield ; Stirling Metals, Limited, Coventry ; Mond Nickel Co. Limited; London ; The British Aluminium Co. Limited, London ; J. Stone & Co. Limited, Deptford ; and Mr. N. I. Bond Williams. for the film of the launching of the *Queen Mary*.

Discussion.

MR. F. PEARSON : Has the lecturer any information as to whether the commercial side of this business is so easy as it appears to be on the quality side ? Some of us still have a lot of difficulty with our material, even ordinary material. When we start dealing with some of these newer materials, shall we not be up against it commercially ?

MR. JONES : The cost question is always a very thorny one. I have tried to suggest that the new metals do require something in the way of revolutionary changes in procedure, and that has caused considerable disappointment during past years, when these metals were brought on to the market, because the suppliers were quite ignorant of the newer production technique. Owing to the success of your labours, and the work of your Institution (I believe these are the main factors) the suppliers of metal now have investigated at considerable length the necessary technique and are prepared to communicate their findings to the user in the form of literature, of which I have collected a quantity in preparation for this lecture. A particularly large volume has been compiled by Thomas Firth and John Brown, Ltd., the forging and steel people, giving full details. Most important people will give information on cutting angles, clearances, speeds, and all necessary details. One then starts experimenting under these ideal conditions, and awaits the reply from the people who receive the superior article. I think you will find commercially that the use of the new materials will show an improved balance sheet. I feel this very strongly to-night, because I do believe that there is every evidence that a large number of engineering firms are already in the market with the newer materials, and I believe that people who do not commence using them now may find themselves left very much behind. Metallurgical improvements have added very much to the qualities of the older types of metals, and I am prepared to listen with sympathy to some one who gets up and insists that " you cannot beat brass and cast iron." For the particular purpose, you cannot, but where there are other and better materials available, if you do not use them soon, someone else will. That, I think, is the spirit of the Institution.

MR. B. T. WARE : The lecturer spoke of the possibility of ultimately doing away with practically all the troubles with piston and cylinder clearances and wear by using a specific type of liner made of special material. Are there any insuperable difficulties in the way of using this material for the cylinder block itself which would seem to be the ideal method of dealing with this trouble ?

MR. JONES : The actual practice which I have quoted of alumin-

ium alloy piston and austenitic cast iron liner is in use to-day in the Diesel engine. Also, in the Diesel engine there is one particular type (I have not got the name in my M.S.) which is built up entirely from rolled steel and welded structure. There is no cast body in which the liner is put; the whole thing is a built-up job, and I feel that is indicative of practice. For the moment, one recognises the difficulties of liners, wet and dry, but those difficulties are rapidly being overcome by improved production technique, and by the close control of the volume change during the manufacturing and service conditions. Difficulties are there, but I feel I am justified in saying that they are rapidly yielding to experience. You are probably familiar with the fact that steel liners, and two or three different types of cast iron liner, are all in use to-day.

Mr. E. T. Cooke: Referring to the last slide, showing a cast iron gear, I should like to ask if the lecturer has any information on the question of distortion of that gear after heat treatment? Also, referring to copper-nickel alloy, I should like to know if he can give any figures on the electrical conductivity of that particular alloy as compared with pure copper? Apropos of the remarks of the first speaker on the question of cost, I should like to quote an instance which occurred recently in my experience, where we were considering the use of stainless steel for certain motor car fittings. It will probably interest the questioner to know that the cost of using stainless steel, polished, in a job where strength was not necessarily the determining factor, came out exactly the same as using an ordinary high carbon steel, polished and chromium-plated (a determining factor in costing). The result was that they could use stainless steel for that particular job at no greater cost than had previously been incurred by using ordinary carbon steel.

Mr. Jones: Would Mr. Cooke mind amplifying his question about copper-nickel alloy and electrical conductivity. Exactly what alloy is it, and why is he interested in the electrical conductivity? Why should he use this alloy instead of copper?

Mr. Cooke: Because I presume that an alloy which can be stressed up to 40 tons tensile would have a very considerable resistance to wear, and might be very interesting to the electrical engineer and production engineer from the point of view of the life of his commutators. Other questions, of course, have to be considered, but the electrical qualities were of more interest.

Mr. Jones: Replying to Mr. Cooke, there are, of course, always distortion problems associated with heat treatment of gears, quenching between dies, and various methods of that description, with a service problem in the case of steel.

I am sorry I cannot give Mr. Cooke any figures as to the total distortion over a particular diameter of gear on quenching. I have not seen that information. Because of the "bewildering array,"

you will forgive me for ignoring the existence of the electrical engineer, and omitting such things as bearing metals. Modern bearing metals tend to be separate from the others. The I.C.I. will, I am sure, give Mr. Cooke figures relating to the conductivity of Kunial metals. I anticipate that the electrical conductivity will not compare with copper. Most of the alloying effects of copper tend to decrease the electrical conductivity and increase wear phenomena, and the considerable decrease in the copper content would mean a considerable decrease in electrical conductivity. I cannot anticipate Kunial metal being substituted, for conductivity, for copper. Thanks for the backing you gave me with the example of stainless steel. I do hope we have to-night encouraged a spirit of discontent with the materials we are using. They may be the very best materials for the job. More probably they are not!

MR. I. H. WRIGHT: I am sure we are very much indebted to Mr. Jones for reminding us of the rate of progress in materials. He has told us something which I do not quite believe, that the production engineer has asked the metallurgist to supply him with all these materials. I want to get some metallurgist sometime to admit that some of these materials are accidental splashes that he has made, and that he is inflicting them on the production engineer as having peculiar properties which he thought the production engineer would appreciate. Metallurgists already have widely extended the number of tests which our materials have to pass before they can be relied upon in service, and I would like to suggest even further regular tests on many of our materials. For instance, the possibilities of the material being suitable for rubbing bearings. After all, a metallurgist who makes ball bearings has got to consider the rolling of ball bearings, and the production engineer cannot always use ball bearings to separate these wonderful materials from each other! There are pistons in cylinders, and there are journal bearings of all kinds, in which rubbing surfaces have to be considered.

I am sorry Mr. Jones said he was not going to talk about bearings, because that is just what I wanted to hear about.

In a particular case where there is a small piece made of one of the R.R. alloys for liners, and which is perfectly lubricated (actually part of an oil-driven mechanism), it has been suggested that this moving piece, which is rather peculiar in shape, should run in a correspondingly-shaped sleeve of the same material. I feel a certain amount of doubt about it. I believe it is the case with these hard aluminium alloys, when they are in the hard condition, that they consist usually of hard crystals in a matrix of alloy, with the crystals properly ground and finished down to a flat surface, but without consideration of wearing qualities. It seems to me that if a piece of that material, in that condition, rubs on another piece of the same material, the crystals will bite each other like rubbing two

files of equal cut together. Whereas if one piece were of a different material, with a different pitch of crystals, it might be like rubbing a dead smooth file on a rough file.

I should like to thank Mr. Jones in that connection for his suggestion of Austenitic cylinder liners and aluminium-alloy pistons, and to ask him whether, if we got one of these pieces of Austenitic alloy, it would be necessary to heat treat it to get the best conditions for a sliding surface? The piece is comparatively small, but its shape is such that it would be very difficult to do anything to it after the piece has been heat treated.

Something has been said about costs, and Mr. Jones has said a good deal about the possibilities of improving business by using the new materials. I suggest that there is a kind of intermediate stage where a good deal of natural courage is required, in that we cannot redesign our machines every time the metallurgist gives us a new material, and the tendency is, if we are open-minded and want to get on, for us to try the new and better materials in the machines as they now are, when of course, some of the qualities of the new materials are not fully taken advantage of. However, we try them out on these machines for some time, until we find they are really better. Then, on re-designing periodically, we really begin to take advantage of the extra lightness of that mounting that the materials allow. In this intermediate stage, when we go on operating our machines with better materials (presuming the machines did work before), we are certainly over-loading our cost-sheets, and I think that the tendency to-day is not to re-design immediately to take advantage of the new materials. The cost of doing that is a hindrance in many cases to the more rapid adoption of these new materials. One of the tests I would impose on the metallurgist is that there should be some means of testing materials for a strictly defined machineability.

MR. JONES: I thank Mr. Wright for his interesting addition to the discussion. That those discoveries are accidental—frankly, they have been, and I leave with you to-night the thought that we have every reason to be confident that there will be fewer accidental discoveries in the future than there have been in the past. Accidental discoveries in the past, even that of stainless steel, have been due to our lack of knowledge of the atom, of the crystal, and of the mechanism of cooling. We have insisted to-night that we have discovered those conditions which are common to all metals, and it will be appreciated that in discovering the conditions which are common to all metals, we are eliminating the surprise element. If we could get all nations in the world to talk the same language, there would be greater understanding, and greater universal progress. Something of that kind is being accomplished by our scientific research, as far as we are particularly interested in metals, a common phenomena

in all metals, so that the surprising and delightful discoveries in the past are just as likely to occur again as we are likely to discover a new America or Australia. The ground is being rapidly mapped out, but we are only just beginning to do it. Infinite resources remain to be discovered, but I do feel we have reached that stage in development where that opinion is beginning to be justified; that the accidental discoveries were just good fortune, and modern science is nowadays getting at the reason for these things, both lots of knowledge coming from a beneficent Providence.

I do not like his suggestion that the metallurgist has inflicted these things on the production engineer. I remember an eminent physicist, whose name I won't mention, saying that he had taken good care never to discover anything useful. There is a gap between scientific resources and their application, and there are many practical difficulties to be overcome, but I do not like to feel we have inflicted them. I do feel that somebody who offers a few thousand pounds' prize for a flight to America or Australia has been the man who has primarily been responsible for putting scientific discoveries into service, and that the production engineer has come along and said, "We can make this available for the man in the street."

Regarding corrosion, I wonder if Mr. Wright has seen that recent publication by the Institution of Automobile Engineers, *Research on Cylinder Wear*? They are saying that cylinder wear is fundamentally not only a rubbing problem, but a corrosion problem, and that it is along these lines that troubles are going to be solved, the production of metals which are not microscopically similar on contact with lubricating mediums. This is quite in its infancy, but it is being done. Did I understand him aright in suggesting the existence of hard crystals in R.R. alloy? (Mr. Wright: "Yes.") There are no hard crystals in heat treated R.R. alloy. R.R. has nothing in common with the older bearing metals which consisted of those hard antimony and compound particles, those hard, brittle particles which do, as he suggests, grind together.

Those benefits which have already been claimed in special constructional materials, are now being met with in ordinary constructional materials, and will soon be available to solve your problems.

Regarding the heat treatment of austenitic alloy, its austenitic conditions depend on its chemical composition, and its rate of cooling. Slight advantages might be obtained by mildly tempering. I thank him for his agreement with the idea that it is worth while to introduce new materials, and in the controversy on new materials and the demand for capitalisation involved, I believe, and I take pains to suggest to my students in engineering and metallurgical technology, that they must always maintain their production

line until their experimental line is beginning to compete with it. That is vitally necessary. Never risk your production with experiments; they must be carried out independently. That does mean capitalisation and courage.

I know of no new test for machineability other than the standard tests already in common use in production circles. The problem is not only one of material, but it is a problem of varieties of cutting angles, clearances, and speed, and these many variables make it very difficult to standardise more than one of them. The final test for anything is doing a job, and we must come down to machining a standard type of section, with standard proportions, with varying tools, in order to get at the present moment any real machineability test.

Future days might give us new methods or use existing methods. It is all in the air.

C. Grew: The lecturer has presented an extremely interesting paper, and I think many of us would welcome an opportunity of putting questions to him at a later date when we have had time to thoroughly digest the same. I should like to have heard something about the aluminium bronze diecasting; there is, of course, nothing new about this alloy, but there seems to be some little difficulty in the production, and certainly the subsequent machining operations, have often presented a problem to the machine shop. Would Mr. Jones also be good enough to say to what extent he considers it possible to alter the ultimate colour of the diecasting. Another little point I should have welcomed some information on; is the development of the metal known as cronite, which is of the heat resisting class, but for some reason does not appear to have reached much popularity.

Mr. Jones: Mr. Ford uses aluminium-bronze die-cast gear wheels. Does that not mean that all difficulties have been got over? Aluminium-bronze is an extraordinary metal. It has a combination of all the useful properties, particularly resistance to corrosion and high strength and heat-treatable properties, but unfortunately these same heat-treatable properties, when they are not under control, do promote, as suggested, a hardness when they are not under control, and it is difficult always to control a die-casting when one has to control the rate of cooling. One cannot slow-cool a die-casting very well. The great problem is to maintain the temperature of the dies, and it is along these lines that optimum properties will be attained.

Control the temperature of the dies with reference to section, for hardness on the surface is essentially a cooling phenomena.

As far as the colour is concerned, a friend of mine continually pulls out of his pocket a gorgeous gold cigarette case, and, when the visitor has sufficiently admired it, and the opulence of the owner,

he proceeds to tell him that it is aluminium bronze, and that it has been in wear for many, many years! Why does Mr. Grew want to alter the colour? I do wish some ingenious person would solve the gold problem by using aluminium bronze! It will be difficult to alter the colour and maintain the properties. I find difficulty in imagining that it will be done. Alteration in properties means alteration in composition. Of course, you know that iron helps in your aluminium bronze. I do not know whether silicon does; it might help, but I am afraid that any serious change in colour would carry with it inevitably change in mechanical properties.

Kronite is a heat-resisting alloy used for furnace work. It is one of those nickel-chromium steels or cast irons. I have not had any personal experience. I am surprised at the small extent to which these heat-resisting alloys are taken up for containers in malleable practice, for example. In furnace work generally, I should suggest to Mr. Grew that an experiment with Kronite would be likely to repay him. It is a nickel-chromium alloy which has been developed along definitely scientific lines. I have not had time to-night to enlarge on friction, resistance to heat, and resistance to strain.

Mr. C. S. Woollard: I know that Mr. Jones could not touch on all the various alloys, but I wish he could have mentioned the addition of cobalt to high-speed steel. I understand it is very difficult to control it. He may be able to solve a little discussion which arose as a result of a test I witnessed recently on some high speed twist drills in which there was cobalt. Four drills had been made from the same bar of steel, and had been heat treated together, but the result was that one did 26 holes, another 37, another 48, and another 68. The point in question arose between the steel makers and the drill manufacturers, to allocate the blame for the lack of uniformity, each blaming the other. I should like to know if Mr. Jones thinks the fault would be with the steel, through lack of uniformity on account of cobalt being difficult to control, or whether it was more likely to be in the heat treatment? Another point I should like to mention is, I wonder if the steel makers are erring on the side of multiplicity of alloys more as a selling point, than the value which is incurred by the increased price?

Mr. Jones: Of course, as Mr. Woollard suggests, if a drill varies, it might be due either to the material or the heat treatment, so that nothing I say must be taken as the last word. Nevertheless I should suggest that it is not due to the material. Cobalt high speed steel will only be made by the steel makers in relatively small quantities; it will be made in the latest contribution of the electrical world and the machine tool world, the high-frequency furnace, where, if necessary, even the atmosphere is under control. I have not met atmospheric control in ordinary routine production of steels but it can

be done. The mixing of metal automatically, due to magnetic currents, tends to promote uniformity. The whole thing is carried out in a way which would delight the production engineer. I find it difficult to imagine that the fault was in the raw material. When it comes to heat treatment, four drills in the same furnace—would you mind telling me the diameter of the drills, and the type of furnace?

MR. WOOLLARD: Thirteen-sixteenths. I do not know the type of furnace.

MR. JONES: You will appreciate that temperature control within very fine limits is very vital in producing uniform results from some classes of material. When buying a tempering furnace, please buy one in which air is circulated over the material, and heat imparted to the steel by that means, rather than the ancient method in which the heat is gradually radiated from some distant spot on to the material, the very opposite of the foot bellows, gas jets, and three bricks. One cannot produce good results from these super alloys by those means. In quantity production, do buy a furnace which will give an even temperature throughout the furnace, or a very gradual temperature gradient to the whole for a moving charge. That is a production job. When you do that with your furnace, you will get results from your material.

I suggest that examination of your heat treatment conditions would reveal that there was a temperature gradient across these test pieces—that one end is hotter than the rest, and probably the hotter end gives the best results. Or, alternatively, that there was a difference in temperature of quenching medium, being quenched in small quantities of liquid. Standardise your conditions, and you will standardise your results. Heating temperature, heating time and quenching conditions do, I think, play a considerable part in the heat treatment.

With regard to the last point, I should feel very doubtful of standing up and saying that any steel makers were not trying to make money! There might be some members of the steelmakers' family who believe that if they call a thing by a different name, they can change the price. There is a definite movement nowadays, particularly from Mussolini's country, to standardise the properties of various alloys, so as to promote a definite order of increase in elastic limit, increase in shaping properties, increase in machining. Thus they have a definite selection of materials, rather than being tempted to buy this alloy or that by the fair words of the man to whom we really owe so much—the super-salesman.

MR. R. H. YOUNGASH: I do not know whether to start by taking sides with the metallurgist or the engineer. It is fairly safe to say that some years ago the engineer took the materials that were available and used them to the best of his ability. Before you, you

have startling evidence of the changes that have come over the question of steels within a comparatively short time, when you remember that all three pieces shown by the lecturer have equal strengths, and it is not so many years ago since we only had that large one available. The engineer started with the materials he had. The scientist was invited, I presume, to improve these materials. Science, in a general way, followed the practice, but to-day we are in a position where the scientist no longer waits to be asked what he can do with a problem, he comes to us and says, " I have discovered certain materials, and here they are, available for your use ! "

The question we have to ask ourselves is whether we always make the best possible use of them. On the other hand, I am equally not quite sure as to whether the scientist or metallurgist has completed his work before he endeavours to interest us, as engineers, in their uses. Take, for instance, one of the oldest materials with which we are familiar, cast iron. When are we going to get iron which can be cast without question into a solid mass ?

I am not so concerned with the question of nickel irons as Mr. Cooke, I have seen many hundreds of cylinder liners hardened with a distortion amazingly small, but I believe I am right when I say there is very little evidence to show that a cylinder liner of nickel iron in a motor car has an appreciably longer life than one of ordinary good quality cast iron.

The difficulty with cylinder wear in motor cars has only become acute since we were induced, by scientists, to use aluminium pistons. Whether they did us a good service or a disservice, time alone will tell, but I think that there we might reasonably ask them to provide us with a material having the weight and specific gravity of something, perhaps, in the neighbourhood of aluminium, but with the wearing qualities of cast iron.

The scientist has developed aluminium to a wonderful degree. Today, the infinite uses to which aluminium and its various alloys are put is a meritorious example of what the scientist can do with material of this sort and, of course, others. We have also in the same class magnesium alloys. Magnesium, as I remember it in early days, was used principally for fireworks. To-day, it is being used, as Mr. Jones has shown, for many purposes which have a definite value to the world. In that connection I should like to ask Mr. Jones whether magnesium alloys are now really stable.

Then we have the nickel chrome steels. The development of nickel chrome steels has done more to alter the whole aspect of engineering and engineering problems than any other material. Whether for strength or cutting qualities or the way they respond to heat treatment leaves us no option but to say that nickel chrome,

or even plain nickel steels have really proved to be one of the most outstanding discoveries in engineering materials.

Mr. Jones referring to furnace work mentioned high chrome steels which have been used for carbonising boxes. So far as nickel chrome, and high chrome steels are concerned, my own experience goes to show that the cost of it is so high that their commercial use does not offer sufficient advantage to persevere with them under present conditions. If that class of material can be brought down appreciably in price then I think full advantage will be taken.

Mr. Jones: I am very grateful to Mr. Youngash for the kind things he has said. It has been a real pleasure to gather together this data, and to realise the resources that are available. The thing which impressed me most was the extent to which the modern engineer has taken them up.

With regard to the casting of solid cast iron, in the first place, too often we find something inside cast iron which is not cast iron. Do run clean iron in, and I feel it will solve lots of your problems. Do consider the contact of the liquid iron with the mould surface. New methods of sand control are well worth investigation. It pays dividends.

I am afraid, with regard to the question of the aluminium piston and the cast iron piston, comparisons prove that the aluminium piston has come to stay. Its weight reduction, reduction of inertia, is such that there is considerable advantage. The high speed engine demands the aluminium piston. I know there are some classes of cars which still fit cast iron pistons, but I do feel the aluminium piston has come to stay. I speak from real experience of the problem of wear. It is still rather a problem, but I think it will be solved to some extent along the lines suggested of revolutionary change in the manufacture of the cylinder block, at one end, and a greater knowledge of the mechanism of wear at the other. Much progress will be made along these lines. There is, however, still a good case for the cast iron cylinder.

With regard to the history of magnesium, it is rapidly making a place for itself for weight reduction, provided there is no stress at high temperatures. Makers tell me that they would not claim a high fatigue stress for magnesium alloys at a temperature above 150° C.

I am very grateful to Mr. Youngash for explaining the reason why I have seen so few heat resisting containers in industrial practice. I have often wondered why, and when I have made some enquiries, the answers have always been rather indefinite. It would explain the fact that the comparative life is not equal to the difference in cost. That is very useful information. Of course, we are going to solve that, I feel, by altering our methods of raising the tempera-

ture, by having radiant heat rather than convective heat in our furnace design. Lastly, with regard to the quality of cast iron, I should find great pleasure in sending you data on alloying cast iron, notes on heat resisting cast iron, and highly alloyed silicon cast iron.